PHOTOSYNTHESIS

WHAT IS PHOTOSYNTHESIS ?

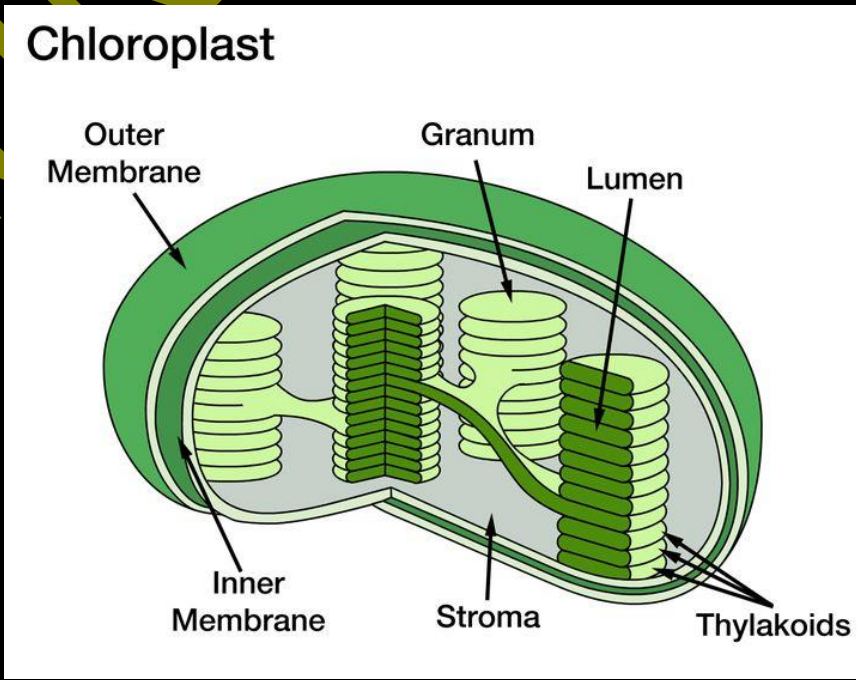
Photosynthesis is an important activity of all green plants which are able to synthesise food from dioxide and water in the presence of chlorophyll and light energy.
Plants produces food resources & release oxygen as a by product during photosynthesis.

Importance of Photosynthesis:

(1) Food for all: Photosynthesis is ultimately the source of energy and food for all living beings directly for plants and indirectly for animals and humans who eat the plants or the plant-eating animals.
(2) Oxygen to breathe in: Photosynthesis is the only biological process which releases oxygen into the atmosphere. Oxygen supports all life on earth.

CHLOROPHYLL - THE VITAL PLANT PIGMENT

Chloroplasts are minute oval bodies bounded by a double membrane, and their interior contains closely packed flattened sacs (thylakoids), arranged in piles (grana) lying in a colourless ground substance called **stroma.**



Chloroplasts are mainly contained in the mesophyll cells located between the upper epidermis and the lower epidermis. Chlorophyll is the green pigment found in plants. It is contained in microscopic cell organelles called chloroplasts. Chlorophyll a and b are most abundant.

Too much light destroys chlorophyll.

The grass growing in the shade under a stone turns yellowish due to the non-formation of new chlorophyll and due to the disintegration of the older one in the absence of light.

REGULATION OF STOMATAL OPENING FOR LETTING IN CARBON DIOXIDE

The main function of the stomata is to let in CO_2, from the atmosphere for photosynthesis. Transpiration occurs along with photosynthesis.

Opening and Closing of Stomata

There are two theories about the opening and closing of stomata.
(1) Potassium ion concentration theory (recent)
(2) Sugar concentration theory (old)

(1) K+ ion concentration theory:

During daytime, the chloroplasts in the guard cells photosynthesise which leads to the production of ATP. This ATP is used to actively pump the potassium ions of the adjacent cells into the guard cells. They become hypertonic so they absorb more water and become turgid. So guards cell bulges and open. Reverse takes place at night.

(2) Sugar concentration theory:

According to the old sugar concentration theory, during daytime, the guard cells begin photosynthesis and the sugar (glucose) produced during the process, increases the osmotic pressure which draws in water from the adjoining cells due to endosmosis. In this way they absorb more water and become turgid. So guards cell bulges and open.

Closing of the stomata: If for any reason, the water content of the leaf is falling short, the water is drawn out of the guard cells due to exosmosis making them flaccid. As a result, their inner thick walls straighten to close the stomata.

PROCESS OF PHOTOSYNTHESIS

Mesophyll cells in a leaf are the principal centres of this activity.

During daytime, when sunlight falls on the leaf, the light energy is trapped by the chlorophyll of the upper layers of mesophyll, especially the palisade cells.
• Carbon dioxide enters the leaf by diffusion stomata.
• Water from the soil is taken up by the roots.

The chemical equation to represent this process is as follows:
$6CO_2 + 12H_2O \rightarrow C_6H_{12}O_6 + 6H_2O + 6O_2\uparrow$

TWO MAIN PHASES OF PHOTOSYNTHESIS

A) LIGHT-DEPENDENT PHASE (PHOTO CHEMICAL PHASE)

In this phase, light plays the key role. A series of chemical reactions occur in thylakoids due to light and so the phase is called photochemical phase.

Two main steps are:
Step I. Activation of chlorophyll: The chlorophyll on exposure to light energy becomes activated by absorbing photons.

Step II. Splitting of water: The absorbed energy is used in splitting the water molecule (H_2O) into its two components (Hydrogen ions and Oxygen) and releasing electrons.

Photolysis causes break down of water in presence of light. It occurs in grana.

End result of the products of photolysis
(1) The hydrogen ions (H^+) are picked up by a compound NADP (Nicotinamide adenine dinucleotide phosphate) to form NADPH.
(2) Oxygen is given out.
(3) The electrons (e) are used in converting ADP (adenosine diphosphate) into energy-rich compound ATP.
This step is called phosphorylation.

B) LIGHT-INDEPENDENT (DARK) PHASE [also called Biosynthetic

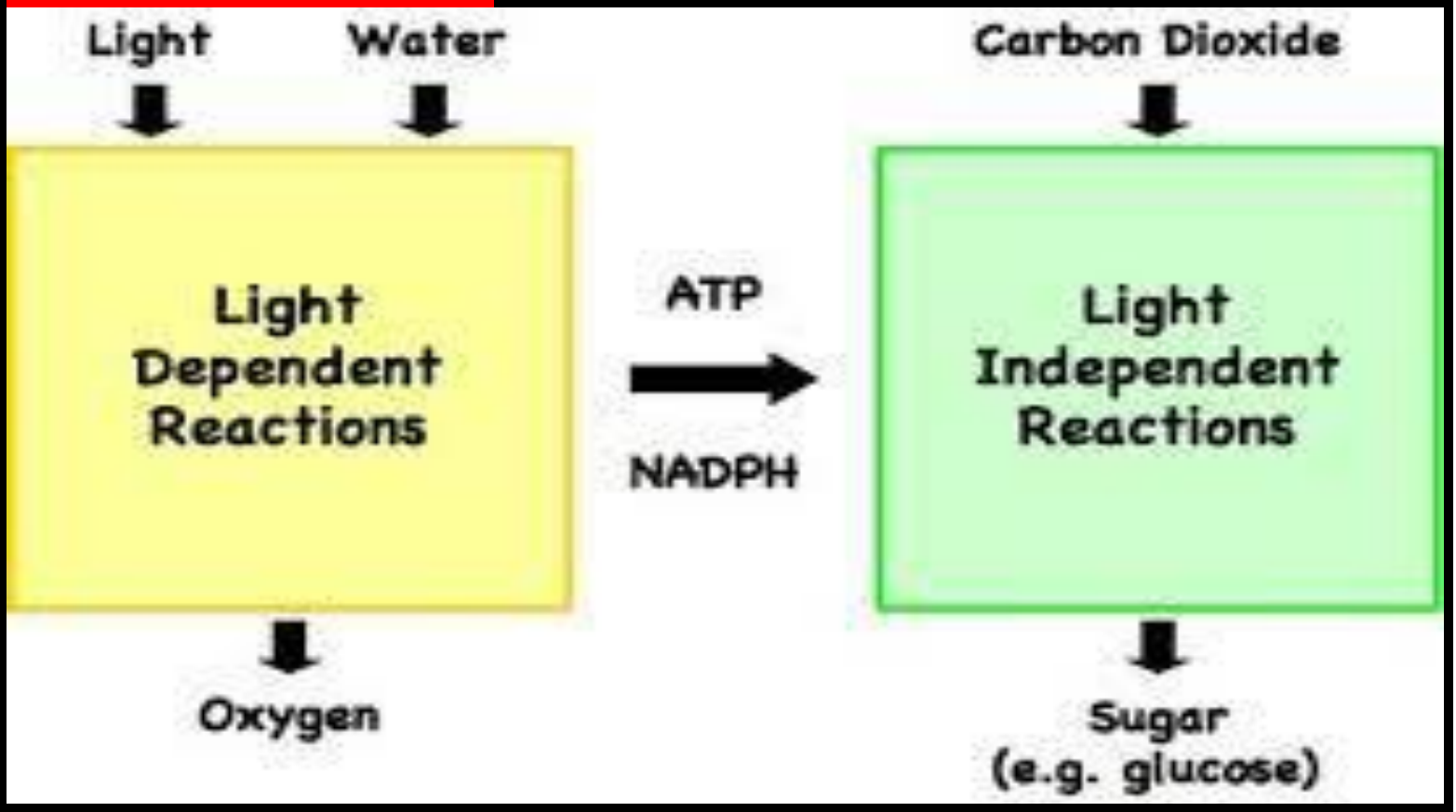
phase]

The old term "dark phase" did not mean that it occurs when it is dark i.e. at night. It only meant that the reactions are not dependent on light. That is why, it is now better to call it "light independent phase."

Conversion of glucose into starch and other chemicals:

Most green plants convert glucose into starch as soon as it is formed during photosynthesis. Several glucose molecules are transformed to produce one of starch; this process is called **polymerisation.**

DIFFERENCE BETWEEN LIGHT DEPENDENT AND LIGHT INDEPENDENT PHASE



ADAPTATIONS IN LEAF TO PERFORM PHOTOSYNTHESIS

1. Large surface area for maximum light absorption.

2. Leaf arrangement at the right angle to the light source to obtain maximum light.

3. Cuticle and upper epidermis are transparent and water proof to allow light to enter freely.

4. Numerous stomata allow rapid exchange of gases.

5. The thinness of leaves reduces the distance between cells facilitating rapid transport.

6. The chloroplasts are concentrated in the upper layers of the leaf to obtain light energy quickly.

7. Extensive vein system for rapid transport to and from the mesophyll cells.

END RESULT OF THE PRODUCTS OF PHOTOSYNTHESIS

1. Glucose: The simple sugar glucose is used in four different ways as required by the plant :
(i) immediately consumed by the plant cells
(ii) stored in the form of insoluble starch
(iii) converted into sucrose
(iv) used in synthesising fats, proteins, etc.

2. Water: The water produced in the process may be re-utilized in the continuance of photosynthesis.

3. Oxygen: Some of the oxygen may be used in respiration in the leaf cells (the phenomenon is called photorespiration).

Utilisation of Synthesised Food and its Translocation:

The glucose is converted into insoluble starch for temporary storage in the leaf. At night, the starch is reconverted into soluble sugar which is transported in solution through the veins of the leaf and down through the phloem of the stem.

FACTORS AFFECTING PHOTOSYNTHESIS

There are four external and three internal factors which affect photosynthesis:

A. EXTERNAL FACTORS

(i) Light intensity and (ii) Carbon dioxide concentration

One would easily think that the rate of photosynthesis will increase with light intensity. To some extent, it is true. Photosynthesis increases with the light intensity up to a certain limit only, and then it gets stabilised at the point S' = (0.02% CO_2). But if, at this point, the carbon dioxide concentration is increased, the photosynthesis also increases further and again gets stabilised at a point S" = (0.05% CO_2) for the two factors together.

(iii) Temperature

With the rise in temperature, the rate of photosynthesis rises. This rise occurs up to the optimum temperature of 35°C after which the rate falls and stops above 40°C.

(iv) Water Content

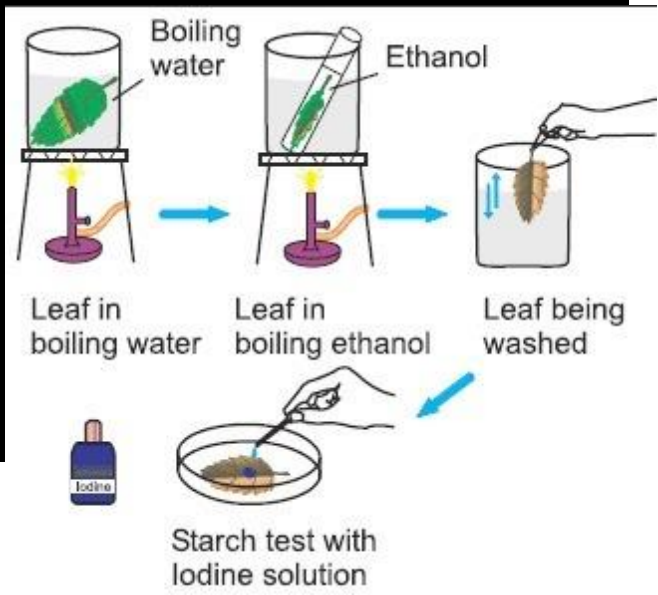
The scarcity of water due to reduced absorption from the soil or due to an excessive loss through transpiration reduces the rate of photosynthesis. Only 1% of water absorbed by the root is utilised in photosynthesis.

B. INTERNAL FACTORS

(i) Chlorophyll - Nutritional deficiencies of minerals cause loss of chlorophyll and hence the drop in trapping solar energy.

(ii) Protoplasm- Dehydration of protoplasm for some reason reduces the rate of photosynthesis. Similarly, the accumulation of carbohydrates also reduces the rate of photosynthesis.

(iii) Structure of leaf- The thickness of cuticle, the distribution of stomata and the size of the leaf influence the amount of light and the amount of CO, entering the leaf.



EXPERIMENTS ON PHOTOSYNTHESIS

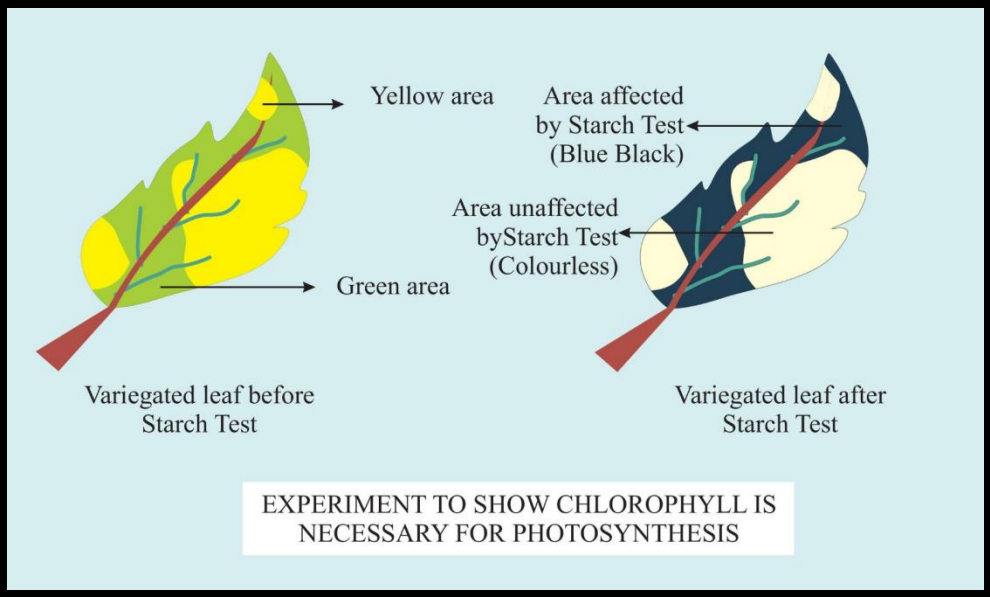
Destarching (Removal of Starch): A plant used for experiments on

photosynthesis should initially be placed in the dark for 24 to 48 hours to destarch the leaves. During this period, all the starch will be removed from the leaves and stored in the storage organs. The leaves will not show the presence of starch.

To test a leaf for starch (Iodine test).

- Dip the leaf in boiling water for a minute to kill the cells.
- Boil the leaf in methylated spirit over a water bath till it becomes pale white due to the removal of chlorophyll .
- Pour hot water to soften it.
- Pour Iodine if it turns blue black, presence of starch confirmed.

Experiment to show that chlorophyll is necessary:



EXPERIMENT TO SHOW CHLOROPHYLL IS NECESSARY FOR PHOTOSYNTHESIS

Experiment to show that sunlight is necessary:

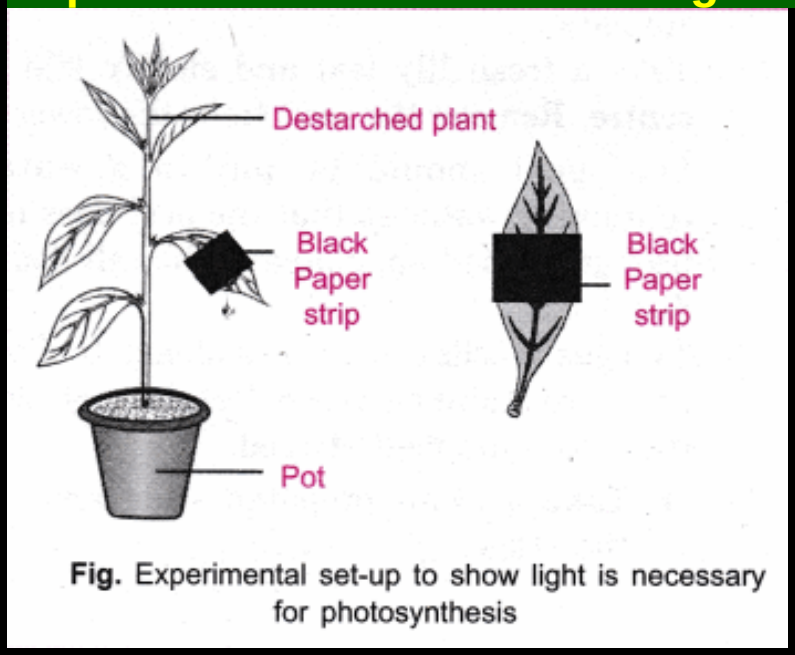
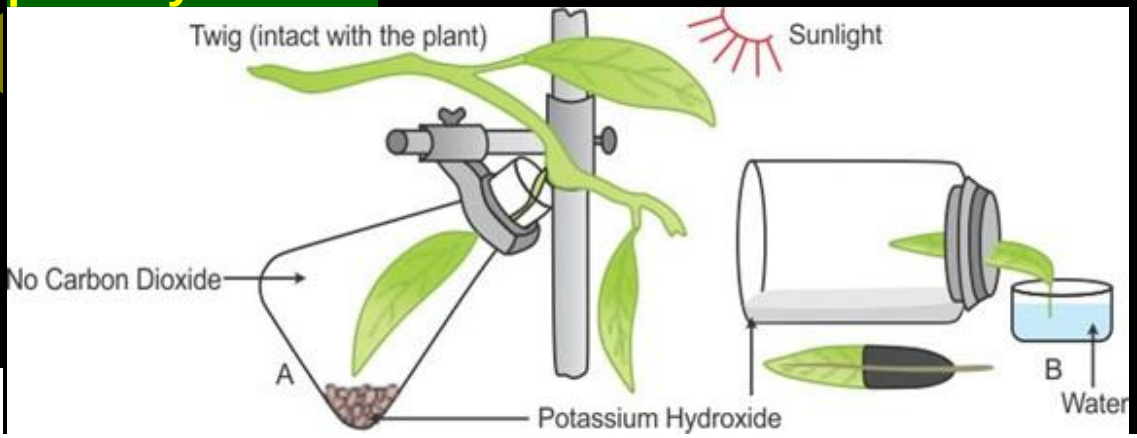
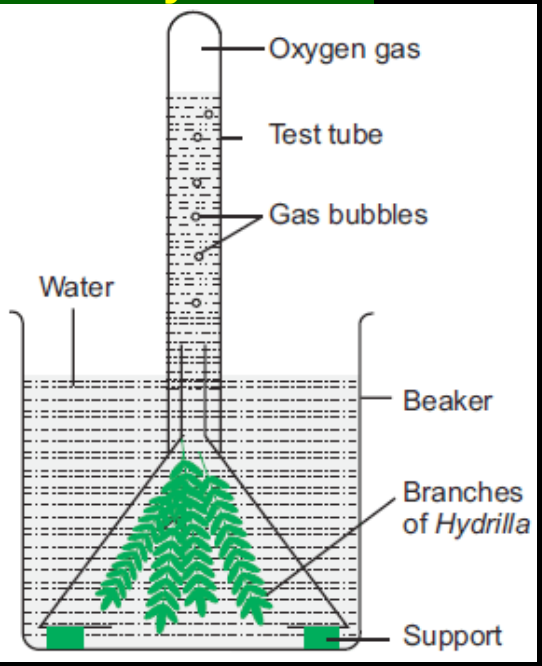


Fig. Experimental set-up to show light is necessary for photosynthesis

Experiment to show that Carbon dioxide is necessary for photosynthesis:



Experiment to show that Oxygen is produced during Photosynthesis:



IMPORTANCE OF PHOTOSYNTHESIS

Photosynthesis supports all life on earth. If there were no green plants, all life on the earth would come to an end.

1. Provides food: All animals, including humans, ultimately depend on plants for food. The food chain may have a number of intervening stages but the starting point is always a plant.

2. Provides oxygen: The life-supporting gas, oxygen, is present in the atmosphere in a free state only because of photosynthesis.

CARBON CYCLE

The carbon cycle is a series of chemical reactions in which carbon as a chemical element (in CO_2 is removed from the air, used by living organisms in their body processes and is finally returned to the air).

The essential steps in the carbon cycle are as follows:

(i) Photosynthesis: Green plants (producers) use carbon dioxide of the air to produce carbohydrates.

(ii) Food chains: Through food chains, the food passes on from plants to animals.

(iii) Respiration: All plants and animals, respire by oxidising carbohydrates in their cells to produce energy and give out carbon dioxide into the atmosphere.

(iv) Decay: The dead remains of plants and animals are consumed by bacteria and fungi and in the process, they break down the organic matter, releasing carbon dioxide back into the atmosphere.

(v) Combustion (burning): When a fuel such as wood or a fossil fuel like coal, petroleum or natural gas, is burnt, the carbon contained in it is oxidised to carbon dioxide, which is given back into the atmosphere. All the fuels named above originally come from living organisms.

(vi) Heating limestone: A certain amount of carbon dioxide is released during heating or burning of limestone in lime kilns.